

PTO/SB/17 (06-07)

Approved for use through 06/30/2007. OMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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Effective on 12/08/2004.

Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL

For FY 2007

☒ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT (\$) 1,370.00

Complete if Known

Application Number	10/714,230
Filing Date	November 14, 2003
First Named Inventor	SUN, Sam-Shajing
Examiner Name	Hall, Asha J.
Art Unit	1709
Attorney Docket No.	036021.0001

METHOD OF PAYMENT (check all that apply)☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____☒ Deposit Account Deposit Account Number: 50-0766 Deposit Account Name: _____

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, except for the filing fee☒ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☐ Credit any overpayments

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FEE CALCULATION**1. BASIC FILING, SEARCH, AND EXAMINATION FEES**

Application Type	FILING FEES		SEARCH FEES		EXAMINATION FEES		Fees Paid (\$)
	Fee (\$)	Small Entity Fee (\$)	Fee (\$)	Small Entity Fee (\$)	Fee (\$)	Small Entity Fee (\$)	
Utility	300	150	500	250	200	100	
Design	200	100	100	50	130	65	
Plant	200	100	300	150	160	80	
Reissue	300	150	500	250	600	300	
Provisional	200	100	0	0	0	0	

2. EXCESS CLAIM FEES**Fee Description**

Each claim over 20 (including Reissues)

Each independent claim over 3 (including Reissues)

Multiple dependent claims

Fee (\$)	Small Entity Fee (\$)
	Fee (\$)
50	25
200	100
360	180

Total Claims **Extra Claims** **Fee (\$)** **Fee Paid (\$)**

5 - 20 or HP = _____ x _____ = _____

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims **Extra Claims** **Fee (\$)** **Fee Paid (\$)**

1 - 3 or HP = _____ x _____ = _____

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims**Fee (\$)** **Fee Paid (\$)****3. APPLICATION SIZE FEE**

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof	Fee (\$)	Fee Paid (\$)
_____ - 100 = _____	_____ / 50 = _____	(round up to a whole number) x _____	_____	_____

4. OTHER FEE(S)

Non-English Specification, \$130 fee (no small entity discount)

Other (e.g., late filing surcharge): Petition for Exception of Unintentionally Delayed Claim for Priority**Fees Paid (\$)**

\$1,370

SUBMITTED BY

Signature		Registration No. (Attorney/Agent) 43,659	Telephone 757-499-8800
Name (Print/Type)	M. Bruce Harper		Date June 19, 2007

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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PTO/SB/21 (04-07)

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**TRANSMITTAL
FORM**

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number 10/714,230

Filing Date November 14, 2003

First Named Inventor SUN, Sam-Shajing

Art Unit 1709

Examiner Name Hall, Asha J.

Attorney Docket Number 036021.0001

ENCLOSURES (Check all that apply)

<input checked="" type="checkbox"/> Fee Transmittal Form <input type="checkbox"/> Fee Attached <input type="checkbox"/> Amendment/Reply <input type="checkbox"/> After Final <input type="checkbox"/> Affidavits/declaration(s) <input type="checkbox"/> Extension of Time Request <input type="checkbox"/> Express Abandonment Request <input type="checkbox"/> Information Disclosure Statement <input type="checkbox"/> Certified Copy of Priority Document(s) <input type="checkbox"/> Reply to Missing Parts/ Incomplete Application <input type="checkbox"/> Reply to Missing Parts under 37 CFR 1.52 or 1.53	<input type="checkbox"/> Drawing(s) <input type="checkbox"/> Licensing-related Papers <input checked="" type="checkbox"/> Petition <input type="checkbox"/> Petition to Convert to a Provisional Application <input type="checkbox"/> Power of Attorney, Revocation Change of Correspondence Address <input type="checkbox"/> Terminal Disclaimer <input type="checkbox"/> Request for Refund <input type="checkbox"/> CD, Number of CD(s) _____ <input type="checkbox"/> Landscape Table on CD	<input type="checkbox"/> After Allowance Communication to TC <input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences <input type="checkbox"/> Appeal Communication to TC (Appeal Notice, Brief, Reply Brief) <input type="checkbox"/> Proprietary Information <input type="checkbox"/> Status Letter <input checked="" type="checkbox"/> Other Enclosure(s) (please identify below): Return Postcard Certificate of Express Mailing
Remarks		

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	Williams Mullen		
Signature			
Printed name	M. Bruce Harper		
Date	June 19, 2007	Reg. No.	43,659

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature			
Typed or printed name	Sharon L. Hardee	Date	June 19, 2007

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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6-20-07

DAC
ZMW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:]	Confirmation No.:	2469
Sam-Shajing SUN]		
]		
Application No. 10/714,230]	Art Unit:	1709
]		
Filed: November 14, 2003]	Examiner:	Asha J. Hall
]		
For: PHOTOVOLTAIC DEVICES]	Attorney Docket No:	036021.0001
BASED ON A NOVEL]		
BLOCK COPOLYMER]		

Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

**PETITION FOR THE ACCEPTANCE OF UNINTENTIONALLY
DELAYED CLAIM FOR PRIORITY UNDER 37 CFR § 1.78(a)**

Dear Sir/Madam:

Applicant hereby petitions for the acceptance of the unintentionally delayed claim for priority under 37 CFR 1.78(a) for the above-referenced pending application. The above referenced pending application was filed with a priority claim referencing a provisional patent application, but this reference included a typographic error in the serial number of such reference (i.e., the incorrect reference to U.S. Provisional Patent Application Ser. No. 60/428,108, wherein the underscored 8 should have been a 6). This typographic error of a single digit was identified upon examination. At no time did Applicant intentionally delay correction of such priority claim; the entire delay was unintentional. In summary, Applicant intended to claim priority to U.S. Provisional Patent Application Ser. No. 60/426,108. With the Commissioner's acceptance, the Applicant intends to amend the above referenced application with such a correction.

This petition is accompanied by a priority claim reference to the prior-filed provisional application, U.S. Provisional Patent Application Ser. No. 60/426,108, in

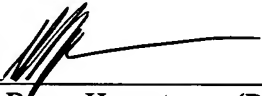
Attachment A. A copy of the U.S. Provisional Patent Application Ser. No. 60/426,108 is provided in Attachment B.

The Commissioner is therefore respectfully requested to accept this correction of the priority claim of the referenced pending application. A fee of \$ 1,370 is believed to be due for this petition. Please charge the required fee to Williams Mullen Deposit Account No. 50-0766.

Date: June 19, 2007

Customer Number: 45309
(757) 499-8800

Respectfully submitted,
WILLIAMS MULLEN



M. Bruce Harper (Reg. No. 43,659)

Attachment A

The present application claims priority from U.S. Provisional Patent Application Ser. No. 60/426,108, filed November 14, 2002, which is hereby incorporated by reference.

Attachment B

PI 1113515

RECEIVED

15 JAN 2004

WIPO

PCT

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME;

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

January 12, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: 60/426,108

FILING DATE: November 14, 2002

RELATED PCT APPLICATION NUMBER: PCT/US03/36538



By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

T. Lawrence

T. LAWRENCE
Certifying Officer

**PRIORITY
DOCUMENT**

SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

11/14/02
13715 U.S. PTO

11-15-02

60426108 . 111402A(1)

Please type a plus sign (+) inside this box →



SUBSTITUTE FOR PTO/SB/16 (2-98)

Approved for use through 01/31/2001. OMB 0651-0037
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
OMB control number.

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)						
Given Name (first and middle [if any])		Family Name or Surname		Residence (City and either State or Foreign Country)		
Sam-Shajing		Sun		427 Willow Brook Way Chesapeake VA 23320		
<input type="checkbox"/> Additional inventors are being named on the _____ separately numbered sheets attached hereto						
TITLE OF THE INVENTION (280 characters max)						
A Photovoltaic Device Based on Conjugated Block Copolymers						
CORRESPONDENCE ADDRESS						
Direct all correspondence to:						
<input checked="" type="checkbox"/> Customer Number 43659 → Place Customer Number Bar Code Label here						
OR Type Customer Number here						
<input checked="" type="checkbox"/> Firm or Individual Name M. Bruce Harper						
Address Williams Mullen						
Address One Columbus Center, Suite 900						
City Virginia Beach		State VA		ZIP 23462		
Country USA		Telephone 757-473-5357		Fax 757-473-0395		
ENCLOSED APPLICATION PARTS (check all that apply)						
<input checked="" type="checkbox"/> Specification Number of Pages 9 <input type="checkbox"/> Small Entity Statement						
<input checked="" type="checkbox"/> Drawing(s) Number of Sheets 3 <input type="checkbox"/> Other (specify) _____						
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)						
<input checked="" type="checkbox"/> A check or money order is enclosed to cover the filing fees						
<input type="checkbox"/> The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 50-0766						
FILING FEE AMOUNT (\$) 75.00						
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.						
<input checked="" type="checkbox"/> No.						
<input type="checkbox"/> Yes, the name of the U.S. Government agency and the Government contract number are: _____						

Respectfully submitted,

Date: 11/14/02

SIGNATURE

TYPED or PRINTED NAME M. Bruce Harper

TELEPHONE 757-473.5357

REGISTRATION NO. 43659

(if appropriate)

Docket Number: 036021.0001

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR

60426108 . 111402

SUBSTITUTE FOR PTO/SB/17 (2-08)
 Approved for use through 09/30/2000. OMB 0651-0032
 Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1.

These are the fees effective October 1, 1997.

Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See forms PTO/SB/09-12. See 37 C.F.R. §§ 1.27 and 1.28.

Complete if Known

Application Number	
Filing Date	
First Named Inventor	Sun, Sam-Shajing
Examiner Name	
Group / Art Unit	
Attorney Docket No.	036021.0001

TOTAL AMOUNT OF PAYMENT 75.00

METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number 50-0766

Deposit Account Name Williams Mullen

☒ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17 ☐ Charge the Issue Fee Set in 37 CFR 1.18 at the Making of the Notice of Allowance

2. Payment Enclosed:

Check ☐ Money Order ☒ Other ☐

FEE CALCULATION

1. BASIC FILING FEE				Fee Description	Fee Paid
Large Entity Fee Code	Small Entity Fee Code	Large Entity Fee (\$)	Small Entity Fee (\$)		
101	201	760	380	Utility filing fee	
106	206	310	155	Design filing fee	
107	207	480	240	Plant filing fee	
108	208	760	380	Reissue filing fee	
114	214	150	75	Provisional filing fee	75.00
SUBTOTAL (1)					(\$) <u>75.00</u>

2. EXTRA CLAIM FEES

Total Claims	Extra Claims	Fee from below	Fee Paid
-**=	<input checked="" type="checkbox"/> X	=	
Independent -**=	X	=	
Claims Multiple Dependent	<input type="checkbox"/> =		

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code	Small Entity Fee Code	Fee Description
103	203	9 Claims in excess of 20
102	202	39 Independent claims in excess of 3
104	204	130 Multiple dependent claim, if not paid
109	209	39 **Reissue independent claims over original patent
110	210	9 **Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$)

FEE CALCULATION (continued)

3. ADDITIONAL FEES				Fee Description	Fee Paid
Large Entity Fee Code	Small Entity Fee Code	Large Entity Fee (\$)	Small Entity Fee (\$)		
105	205	130	65	Surcharge - late filing fee or oath	
127	227	50	25	Surcharge - late provisional filing fee or cover sheet	
139	239	130	130	Non-English specification	
147	247	2,520	2,520	For filing a request for reexamination	
112	212	820*	820*	Requesting publication of SIR prior to Examiner action	
113	213	1,840*	1,840*	Requesting publication of SIR after Examiner action	
115	215	110	55	Extension for reply within first month	
116	216	380	190	Extension for reply within second month	
117	217	870	435	Extension for reply within third month	
118	218	1,360	680	Extension for reply within fourth month	
128	228	1,850	925	Extension for reply within fifth month	
119	219	300	150	Notice of appeal	
120	220	300	150	Filing a brief in support of an appeal	
121	221	280	130	Request for oral hearing	
138	238	1,510	1,510	Petition to institute a public use proceeding	
140	240	110	55	Petition to revive - unavoidable	
141	241	1,210	605	Petition to revive - unintentional	
142	242	1,210	605	Utility issue fee (or reissue)	
143	243	430	215	Design issue fee	
144	244	580	290	Plant issue fee	
122	222	130	130	Petitions to the Commissioner	
123	223	50	50	Petitions related to provisional applications	
126	226	240	240	Submission of Information Disclosure Stmt	
581	281	40	40	Recording each patent assignment per property (times number of properties)	
146	246	760	380	Filing a submission after final rejection (37 CFR 1.129(a))	
149	249	760	380	For each additional invention to be examined (37 CFR 1.129(b))	
Other fee (specify)				Late filing fee/declaration surcharge	
Other fee (specify)					
*Reduced by Basic Filing Fee Paid					
SUBTOTAL (3)					(\$)

SUBMITTED BY

Complete (if applicable)

Typed or Printed Name	M. Bruce Harper	Reg. Number	43659
Signature		Deposit Account User ID	50-0766
Date	14 Nov 02		

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office.

60426108.111402

Certificate under 37 CFR 1.10 of Mailing by "Express Mail"

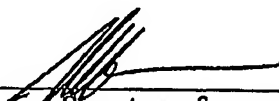
EJ047666794US

"Express Mail" label number

14 NOV 02

Date of Deposit

I hereby certify that this correspondence is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Box PROVISIONAL PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231.



Signature of person mailing correspondence

M. BRUCE HARPER

Typed or printed name of person mailing correspondence

Note: Each paper must have its own certificate of mailing by "Express Mail".

036021.0001

Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

A Photovoltaic Device Based on Conjugated Block Copolymers**BACKGROUND OF THE INVENTION****Field of the Invention:**

The present invention relates to the field of photovoltaic or opto-electronic devices. More particularly, this invention relates to cost effective, lightweight, and flexible shaped "plastic" photo detectors and "plastic" solar cells (renewable and clean energy generation), etc.

Background

Photovoltaic (PV) is a process where light is absorbed by a media and is then converted into a voltage or electric current. When light strikes certain materials, the photons in the light excite electrons in the material. In some materials, there are free electrons that are released by the interaction with the photon; the movement of that electron leaves a hole. The flow of the electron, along with the resulting holes creates electric current. Most of the PV cells used today are based on inorganic semiconductor materials such as silicon, although other materials, such as Gallium Arsenide, Cadmium Telluride, Copper Indium Diselenide are also used.

The typical silicon based solar cell uses a semiconductor pn-junction. The cell comprises semiconductor layers, one of which is n-doped (doped with atoms of excess valence electrons) and the other is p-doped (doped with atoms lacking a valence electron); their interface forms a pn-junction. The n-doped layer is characterized by

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Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

excess electrons, while the p-doped layer is characterized by holes. In other words, the n-doped layer is a donor (D) of electrons, and the p-doped layer is an acceptor (A).

Initially the doped materials reach equilibrium across the pn-junction. When sunlight strikes the material, the light is absorbed in the excitation of the excess electrons, which are released and create a charge separation along the pn-junction; a transport of electrons and holes creates the electrical current that is collected by electrodes.

The high cost of manufacturing traditional inorganic photovoltaic materials and devices has led to significant research into alternative photovoltaic materials, as well as how to configure those materials within the solar cells. Additionally, improved efficiency could lower the lifetime cost and make photovoltaic devices a more commercially attractive and environmentally friendly energy alternative. One area of research is the use of organic materials to fabricate solar cells, such as using semi-conducting conjugated polymers, liquid crystalline structures, etc. Organic materials, including polymers, are relatively inexpensive, lightweight, flexible, and easily manufactured in comparison to their inorganic counterparts.

However, semi-conducting polymers work differently from inorganic semiconductors. Semi-conducting polymers are long molecules that have repeating structures and with alternating single and double carbon-carbon bonds, and are referred to as being "conjugated." The double bonds (also called π bonds) within conjugated polymers generate a highest occupied molecular orbital (HOMO) that is typically filled with π electrons, and a lowest unoccupied molecular orbital (LUMO) that is typically

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Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

empty without light or other forms of excitation. The HOMO or LUMO of each double bond in a conjugated polymer backbone interact with each other and form HOMO and LUMO bands, the energy difference between the two bands is generally called band gap, or sometimes also called the "optical gap".

Most conjugated polymers appear to have a band gap that lies in the range of 1–3 eV, which makes them ideally suited for light harvesting or photovoltaic devices working in the visible light range. The photo-induced electron transfer and charge (electron-hole) separation observed in conjugated organic composites of the donors (electron-donating or p-type organic species) and acceptors (electron-withdrawing or n-type organic species) provide an alternative to traditional inorganic solar cells.

The mechanism for an organic approach to high efficiency light harvesting or photovoltaic conversion has been developed. Specifically, in organic photovoltaic materials, for instance, light generated excitons (e.g., electron-hole pairs) can typically diffuse 20 nm in their lifetime. The charges (electrons and holes) can be separated at the contact interface between the donors and acceptors, where for donor excitons, the electrons are transferred from donor's LUMO to the acceptor's LUMO and for acceptor excitons, the holes transferred from acceptor's HOMO to the donor's HOMO, provided that the corresponding energy level differences between the donor and acceptor are big enough to overcome the exciton binding energy (typically 0.5 eV). Next, and mainly due to the asymmetry of the photovoltaic cell, the electrons travel and are collected at the negative electrode, and holes travel and are collected at the positive electrodes. One of

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Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

the main scientific challenges for a high efficiency organic photovoltaic device is to fabricate a nano structure where both the donor and acceptor phases have dimensions within the typical organic exciton diffusion range (about 20 nm), yet are continuous between the two electrodes.

DESCRIPTION OF THE INVENTION

The present invention is a potentially efficient organic photovoltaic device made of a -DBA- or an analogous block copolymer system, where D is a donor derivatized conjugated polymers, oligomers, or equivalent (also referred as "conjugated donor block"), A is an acceptor derivatized conjugated polymer, oligomer, or equivalent (also referred as "conjugated acceptor block"), B is a non-conjugated (such as aliphatic) bridge unit. The said block polymer system may also be embodied in, refer to, or be represented as -ABD-, -DBAB-, -ABDB-, -BDAB-, -BABD-, -DBABD-, -ABDBA-, etc.

The present invention comprises the structure and fabrication process of a polymer or "plastic" thin film photovoltaic device that possesses benefits of lightweight, flexible shape, cost effectiveness, and potentially very high power conversion efficiency in comparison to current commercial inorganic semi-conductor based photovoltaic devices. This "plastic" photovoltaic device has the following features:

- 1) A conjugated donor block (D) is covalently connected with a conjugated acceptor block (A) via a short non-conjugated bridge unit (B) to form a -DBA- or its analog type block copolymer chemical structure, as shown in Figure 1. Preliminary experimental

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Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

work has shown the -DBAB- type to be a useful embodiment. Those skilled in the art will readily see that a variety of configurations could be produced for specific applications or specifications. Preferably, the donor and acceptor blocks should be chosen, configured, or built in such a way that the band gap of both donor and acceptor phases in solid states substantially match the optical radiation energy of the intended applications or devices. This -DBA- and its analog type polymer backbone structure or "Primary Structure" can be realized via common organic design and synthesis.

2) Additionally, both the donor and acceptor conjugated block backbones may be self-assembled in a solid thin film state to form a π -orbital stacked or adjacent block chain closely packed structures, as shown in Figure 2, as in many conjugated polymer systems, so that the π -orbitals between adjacent backbones are well coupled or overlapped to each other. This may be called a "Secondary Structure".

3) Additionally, the donor and acceptor block should be sufficiently different from each other, so that in solid thin film state, donor and acceptor blocks will be able to phase separate from each other as seen in many block copolymer systems. The donor and acceptor separated phases may be self-assembled to form a columnar or "Honeycomb" shaped structures, as is the general case known in many di- or tri-block copolymer systems.

036021.0001

Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

It is known that the incompatibility between the blocks leads to the formation of many unique micro- or nano-phase separated and ordered structures, including, but not limited to, lamella, columnar, cubic centered lattice, etc., and a specific phase separated structure is determined by chemical composition, size of each block, temperature, and other factors. For instance, a recent report of MEH-PPV/Polystyrene- C_{60} donor/acceptor di-block copolymer system indeed exhibited a "honeycomb" shaped nano structure.

Each donor phase column should interface with at least one acceptor column, and vice versa. The diameter of each column should be approximately within the corresponding effective exciton diffusion length of the respective donor or acceptor blocks (typically about 20 nm).

Finally, a thin layer of donor block may be coated on one side of the columnar or "Honeycomb" structure in perpendicular to the column direction in order to form a positive side of the photovoltaic device, and a thin layer of acceptor block will likewise coated on the other side of the "Honeycomb" to form a negative side of the PV device. Other forms of aligning or directing charge as is known in the art will serve as well. Finally, a conducting electrode with a work function close to, or substantially appropriate to the HOMO levels of the donor placed in contact to the donor (positive) layer side of the device will collect holes, and a conducting electrode with a work function close to, or substantially appropriate for the LUMO levels of the acceptor placed in contact to the acceptor layer (negative) side to collect electrons. At least one electrode should be

036021.0001

Title: A Photovoltaic Device Based on Conjugated Block Copolymers

Inventor: Sam-Shajing Sun

transparent to the intended light radiation. This may be called "Tertiary Structure" of the said PV cell, as shown in Figure 3.

In the present invention, a -DBAB- type block copolymer system has already been synthesized and characterized recently, where D is an alkyloxy donor derivatized poly-(1,4)-phenylenevinylene (PPV), abbreviated as "RO-PPV", A is a sulfone acceptor derivatized PPV, abbreviated as "SF-PPV-I", and B is a non-conjugated aliphatic bridge unit. Preliminary electron microscopic study has revealed interesting regular nano-phase separated morphological pattern in a drop dried -DBAB- film. A donor or acceptor derivatized polythiophenes, or other similar type materials, may also be used as the conjugated blocks. A non-conjugated bridge unit provides an energy barrier between the bands of the donor and acceptor blocks in order to prevent a convenient electron-hole recombination. The bridge also makes the donor or acceptor rigid blocks less vulnerable to distortion, and more convenient to self-assemble. Conjugated π orbital distortion due to molecular thermal vibrations or backbone twist typically interrupts conjugation and therefore reduces charge mobility.

In summary, the backbone structure -DBA- and its analogs may be called a "Primary Structure". Since the π orbital overlap between rigid blocks are useful for charge mobility, this self-assembly morphology between blocks could be called a "Secondary Structure". Finally, the block copolymer "honeycomb" morphology provides

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smooth "tunnels" for charge transportation to the respective electrodes. The "honeycomb" structure may be sandwiched between a thin layer of donor film (in contact with a positive electrode), and a thin layer of acceptor film (in contact with a negative electrode) so that an efficient asymmetric polymeric photovoltaic device is thus formed. The sandwiched "honeycomb" structure can be called a "Tertiary Structure". Another advantage of this system is that the interfacial area and the phase size can be tuned via block copolymer segment size, therefore, the opto-electronic conversion efficiency can be easily optimized via materials design and synthesis.

CLAIMS

What is claimed is:

1. A photovoltaic primary structure comprising:

a conjugated donor block,

a conjugated acceptor block, and

a non-conjugated bridge covalently coupling said donor block and said acceptor block.

2. The photovoltaic primary structure as described in claim 1, wherein a second non-conjugated bridge is covalently coupled to one of either said acceptor block or said donor block, and said second non-conjugated bridge is capable of coupling to other such photovoltaic primary structures to form a repeating chain.

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3. A photovoltaic secondary structure comprising a plurality of primary structures in a π orbital stack and closely packed morphology.
4. A photovoltaic tertiary structure comprising a plurality of secondary structures in a phase separated columnar nano-structure.
5. A photovoltaic tertiary structure as described in claim 4, further comprising a donor thin layer at a first end of such columnar nano-structure and an acceptor thin layer at an opposing second end of such columnar nano-structure, wherein said donor thin layer and said acceptor thin layer are oriented to such columnar nano-structure so as to form an asymmetric geometry.
6. A process for producing a photovoltaic primary structure comprising the steps of
 - producing a conjugated donor block,
 - producing a conjugated acceptor block, and
 - covalently coupling said donor block to said acceptor block with a non-conjugated bridge.

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☒ Declaration Submitted With Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	036021.0001
First Named Inventor	Sun, Sam-Shaling
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

A Photovoltaic Device Based on Conjugated Block Copolymers

the specification of which

(Title of the Invention)

☒ Is attached hereto
OR

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I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

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Name of Sole or First Inventor

☐ A petition has been filed for this unsigned inventor

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Family Name or Surname

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Inventor's
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